EFFECT OF STABILITY, PRECISION AND CONCENTRATION EXERCISES ON SHOOTING ABILITY AND PLANTER OSCILLATION OF SHOOTERS

Proposed By

Amit Pal

(Research Scholar)

Proposed Supervisor

Dr. C.P. Singh Bhati

Lakshmibai National Institute of Physical
Education, University of Gwalior, Madhya Pradesh

A Synopsis Submitted to

Lakshmibai National Institute of Physical
Education, University of Gwalior, Madhya Pradesh

For

The Degree of

DOCTOR OF PHILOSOPHY (Ph.D.)

July, 2022

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DEPARTMENT OF SPORT PSYCHOLOGY

CERTIFICATE

I hereby declare that the short synopsis "EFFECT OF STABILITY, PRECISION AND CONCENTRATION EXERCISES ON SHOOTING ABILITY AND PLANTER OSCILLATION OF SHOOTERS" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Physical Education under the department of Sport Psychology of Lakshmibai National Institute of Physical Education, Gwalior, during the academic year 2022.

It is a bonafide record of original work carried out under the supervision of Dr. C.P. SINGH BHATI and has not been submitted in full or part to any other university or institute for a degree or diploma.

13/05/2025

(AMIT PAL)

13.5.25

Supervisor,
Dr. C.P. SINGH BHATI
Head, Department of yogic science

13/5/25

(Chairman, DRC)

Introduction

Balance and stability are the foundation of success in those sports requiring precision like shooting. In biomechanics, the balance is the ability to hold the body's center of gravity in the base of support with minimal postural sway (Shumway-Coo and Haller, 1988). Core stability – the static contractions of trunk muscles, and postural stability – the reflexive activity of lower extremities and core muscles – are the key to minimizing body sway in static body postures (Anderson and Plecas, 2000). Stability, either static or dynamic, is fundamental for performance in sports that depend on precision. Stability is highly dependent on the proper working of the position control system which combines feedback from the vestibular, visual and proprioceptive systems (Peterka, 2002; Cenciarini et al., 2010). Among them, the vestibular sense is very important for regulation of the body's balance and returning it back to its center of gravity and maintaining postural stability (Petreka, 2004; Jeka et al., 2004). This complicated interaction between sensory and physical systems guarantees that athletes can be stable, even in dynamic environments.

In shooting sports, stability as well as precision play a critical role in performance. The accuracy of shooting and shooting scores depend not only upon the strength of the upper body, but also on the stability of the posture of the shooter (Ravindra et al., 2009). It has been found that elite shooters have far less body sway than less experienced shooters during standing and shooting positions (Niinimaa & McAvoy, 1983; Aalto et al., 1990). In addition, experienced shooters show superior postural stability that is related to the accuracy of shooting (Era et al., 1996; Ball et al., 2003a). This shows direct relationship between balance and shooting success where talented athletes have better balance when shooting. On the other hand, novice shooters are characterized by increased postural instability, hence inconsistent shooting performance (Era et al., 1996).

Rifle and pistol shooting as well as other shooting sports require mental concentration, physical stability, and accurate aiming. An efficient shooting platform is very important for the best performance, and any instability, e.g., plantar oscillation (small foot movements), can worsen accuracy. Stability exercises teach shooters how to keep an even base while precision exercises improve their shooting accuracy. Such exercises of both types support the improvement of shooting performance, decreasing the probability of mistakes, and increasing focus at the shot. So, knowing how stability and precision affect shooting is key to building training programs that raise shooting performance.

Background

Shooting sports are quite specific and involve special physical, mental and technical skills whereas precision sports such as rifle and pistol shooting involve a specific combination of physical and psychological skills. Balance and stability are critical to the performance of athletes among these. Good stability during shooting helps to reduce body sway and raise shooting accuracy. The control of the posture, even under pressure, has direct bearing to the success of the shot. Shooting performance at an elite level depends greatly on how well stability and mental focus work together.

Balance, in biomechanics, is the capability to keep the center of gravity of the body in the base of support and with minimal postural sway (Shumway-Coo and Haller, 1988). Static contraction of trunk muscles that is core stability is important in minimizing body sway in static positions such as those found in shooting sports (Anderson and Plecas 2000). The over-all functioning of the body's position control system, including the integration of sensory input from the vestibular, visual and proprioceptive systems, is critical in maintaining proper postural stability (Peterka, 2002; Cenciarini et al., 2010). The vestibular sense specifically, is what controls reflexive movements of the body and keeps it balanced, even when under high levels of stress or physical strain (Petreka, 2004; Jeka et al., 2004).

The need for balance and stability is clear in the manner in which elite athletes do shooting sports. Research has determined that elite shooters experience low body sway when standing and while shooting, compared to lesser experienced athletes (Niinimaa & McAvoy, 1983; Aalto et al., 1990). In addition, experienced shooters demonstrate better postural control, which is related to higher accuracy of shooting (Era et al., 1996). By contrast, the less skilled shooters exhibit higher level of postural instability, which has a negative effect on their shooting performance (Era et al., 1996; Ball et al., 2003a).

Stability of shooting platform is an important skill for shooting sports. Plantar oscillation, the slight movement of the foot in shooting, can have a major effect on stability and accuracy. Thus, specific training exercises that will help improve balance and stability are essential in the case of shooters who want to improve their performance. Exercises that improve the core and proprioceptive feedback help shooters stay steady, reduce body movement, and increase shooting accuracy.

This study, therefore, aims at examining the effect of stability, precision and concentration exercises on shooting ability and postural stability in shooters. Investigating the effects of these

exercises, the study seeks to add to the understanding of the ways in which balance and stability training can improve shooting and decrease instability in shooting tasks.

Review of Related Literature

To investigate the body stability during shooting at a stationary target in a standing position, Krawczyk-Suszek et al. (2022) performed a randomized controlled trial. They discovered that postural stability relied on such variables as physical activity that was particularly critical in sports that involved precision when standing. They noted that reduced body fatigue resulted to improved shooting accuracy. The study sought to determine how physical effort impacted the deflection of center of gravity, the length of the COP path and ground reaction forces in non-regular exercisers. The participants in the study were 139 (average age 23.1 years). 46.8% male, 53.2% female). Participants executed static balance tests and shooting tasks two times in a multimedia shooting range. They were randomized into two groups. Between the static tests, Group X performed the Harvard test, while Group Y served as the control group, and did not perform the test. The study measured ground force reactions using the Zebris PDM-L platform. Group X had an increase in the length of the COP path, COP speed and 95% confidence ellipse area following the Harvard test. No significant changes were observed in Group Y. The researchers concluded that physical effort deteriorated the postural stability, which was evidenced by the elevated balance-related parameters during shooting.

In 2011, Hrysomallis, C. reviewed to examine the relationship between balance ability and athletic performance. The review compared balance skills in athletes from different sports and whether athletes of higher level of competitions had better balance. It also reviewed balance in relation to certain performance measures and the impact of balance training on sport performance and motor skill. The review established that gymnasts had the best balance, followed by soccer players, swimmers, active controls and finally basketball players. There were no comparisons of rifle shooters with other athletes. However, among sports such as rifle shooting, soccer and golf, elite athletes were seen to have better balance than less skilled players. This was not the case in alpine skiing, surfing and judo. Balance ability was strongly associated with archery and rifle shooting accuracy, skating and luge start speed in ice hockey. It had no strong relationship with snowboarding scores or accuracy of baseball pitching. Also, the review found that elite athletes were overall better balanced in certain sports. Balance ability, overall, was highly associated with multiple performance dimensions. The author suggested further research to test how balance training could enhance motor skills of elite athletes.

Ravindra et al. (2009) examined shooting accuracy among three groups of pistol shooters in order to determine the influence of experience, eye condition and time available to view on performance. The study was concerned with cognitive issues such as aiming and the time to bring sights into line with the target. Twenty-one male university students took part, with an experienced group of gas pistol shooters, a group of video shooting game players and a control group of those without any shooting experience. The results indicated that experience shooting had significant effects on both mean and RMS shooting errors. It was also established that experienced shooters had the best performance when viewing time was less than 2 seconds, whereas novices required approximately 3 seconds for good performance. Two models were formulated to describe how limited viewing time was influencing performance, both of which were good fits to the data for viewing times less than 2 seconds. According to the study, the main reason for the difference in performance was postural balance, and not aiming skills or other cognitive factors.

Mononen et al. (2007) examined the manner in which shooting accuracy was associated with postural balance and gun barrel stability in novice rifle shooters, between and within individuals. They assessed postural balance with sway velocity anteroposterior (VELAP) and mediolateral (VELML) and rifle stability with horizontal (DEVH) and vertical (DEVV) aim deviations. 30 standing shots from 10 meters were made by 58 participants. Results revealed that only for postural balance and rifle stability was there a significant inter-individual relation to shooting accuracy, with correlation coefficients from -0.29 to -0.45. A regression analysis revealed that VELML and DEVH as a combination accounted for 26% of shooting score variance. The study concluded that postural balance had both direct and indirect effects on accuracy of shooting thus balance training could be used to enhance performance.

The key factors that influence pistol shooting accuracy were the subject of study of Mason et al. (1990). Their biomechanical examination of elite pistol shooters revealed that body sway and pistol movement both were related to shooting performance. Body sway had a predominant effect on vertical shot drop-off, while pistol movement influenced horizontal scatter. The two factors were found vital for shooting accuracy and acted independently according to the study. It also emphasised the use of time as used during final aiming. In addition, the study revealed significant differences in the ways in which these factors affected elite athletes' shooting accuracy.

Objectives of the Study

Assessing the Influence of Stability Exercises:

- To test the impact of targeted stability exercises on general stability and postural control of the shooters.
- To measure the amount of changes in significant stability parameters (sway, balance, and proprioception) that have occurred due to the application of specific stability training regimens.

Evaluating Precision Exercise Effects on Shooting Accuracy:

- To examine the effect of precision-oriented exercises on marksmen shooting accuracy and consistency.
- To analyse changes in shooting technique, muscle coordination and fine motor skills that result from precision training interventions.

Concentration Exercise Influence on Marksmanship:

- To measure the impact of concentration exercise on mental focus, attention and cognitive areas of shooting performance.
- To examine how continued concentration can be used to minimize errors and improve decision making during shooting activities.

Measuring Plantar Oscillation Dynamics:

- To measure and define the plantar oscillation patterns shown by shooters in static and dynamic shooting postures.
- To establish the connection between plantar oscillation parameters and shooting performance with the view to understand the relationship between foot dynamics and shooting.

Integrated Examination of Stability, Precision, and Concentration:

- To examine synergistic effects of combining stability, precision and concentration exercises in total shooting performance.
- To identify possible interaction and interdependence among the three components of training for best performance results.

Development of a Comprehensive Training Protocol:

- To develop a comprehensive and integrated training protocol which will include stability, precision and concentration work.
- To offer a systematic and evidence-based guide for coaches and athletes to increase shooting prowess by the use of a comprehensive training program.

Hypotheses:

Assessing the Influence of Stability Exercises:

- Null Hypothesis (H_0): Targeted stability exercises have no significant effect on the overall stability and postural control of shooters.
- Alternative Hypothesis (H_1): Targeted stability exercises have a significant effect on the overall stability and postural control of shooters.

Evaluating Precision Exercise Effects on Shooting Accuracy:

- Null Hypothesis (H_0): Precision-focused exercises have no significant impact on the shooting accuracy and consistency of marksmen.
- Alternative Hypothesis (H_1): Precision-focused exercises have a significant impact on the shooting accuracy and consistency of marksmen.

Concentration Exercise Influence on Marksmanship:

- Null Hypothesis (H_0): Concentration exercises have no significant influence on the mental focus, attention, and cognitive aspects related to shooting performance.
- Alternative Hypothesis (H_1): Concentration exercises have a significant influence on the mental focus, attention, and cognitive aspects related to shooting performance.

Measuring Plantar Oscillation Dynamics:

- Null Hypothesis (H_0): Plantar oscillation patterns exhibited by shooters during static and dynamic shooting stances have no significant correlation with shooting performance.
- Alternative Hypothesis (H_1): Plantar oscillation patterns exhibited by shooters during static and dynamic shooting stances have a significant correlation with shooting performance.

Integrated Examination of Stability, Precision, and Concentration:

- Null Hypothesis (H_0): There are no synergistic effects of combining stability, precision, and concentration exercises on overall shooting ability.
- Alternative Hypothesis (H_1): There are synergistic effects of combining stability, precision, and concentration exercises on overall shooting ability.

Development of a Comprehensive Training Protocol:

- Null Hypothesis (H_0): A holistic and integrated training protocol, incorporating stability, precision, and concentration exercises, has no significant effect on enhancing shooting abilities.
- Alternative Hypothesis (H_1): A holistic and integrated training protocol, incorporating stability, precision, and concentration exercises, has a significant effect on enhancing shooting abilities.

Research Methodology

Research Design

The current research was conducted with a quantitative design of research to scientifically measure the influence of stability, precision and concentration exercises on the ability to shoot and plantar oscillation among male shooters. The research was experimental in nature, and aimed at finding causal relations between the independent variables, namely stability, precision, and concentration exercises, and the dependent variables, namely shooting performance and balance, assessed via center of pressure (C.O.P.) analysis. The present study was aimed at investigating both physical and psychological aspects of shooting performance through a structured and controlled intervention.

A 45-day structured training program was designed and undertaken as the main intervention strategy in this research. This program combined theoretical teaching and practical exercises to improve static shooting skills, stability control and concentration skills. Activities were static shooting drills, balance and stability exercises, concentration exercises to enhance focus when under pressure. The program was properly designed to slowly test the participants and give adequate skill development in the six weeks. Pre and post intervention measurements were systematically made to determine measurable improvement of shooting accuracy and postural stability.

The study was in the nature of pre-test and post-test experimental model, and data was collected at two main points- before the beginning of 45-day training and after its completion. This design was capable to provide objective evaluation of the effectiveness of the training program by comparing performance metrics at these two points. Paired t-tests were used to perform statistical analysis of shooting scores and C.O.P. data, descriptive statistics and correlation analysis were used to analyze the correlation between balance improvements and shooting performance. The structured layout and powerful statistical mechanisms enabled a broad and accurate assessment of the influence of the training program on the participants' general shooting skill and postural stability.

Participants and Sampling

The subjects of the present study were 30 male athletes who were actively engaged in shooting sports. Such participants were also randomly selected from the Lakshmibai National Institute of Physical Education (LNIPE), Gwalior where a focused and homogenous sample group was chosen. Participants were chosen using the method of random sampling with a view to reducing selection bias as well as to increase representativeness of the sample. Random sampling ensured that all eligible male shooters of the institute had equal opportunities for selection in the study thus promoting validity and generalizability of results to the target male shooter population.

All participants were chosen based on certain inclusion criteria that stipulated that participants should be characterized by a consistent and uniform background of shooting training and experience, which helped in reducing variability due to physiological and experiential differences. Such homogeneity enabled us to be more confident that the effects that we found during the study were more likely attributed to the intervention and not individual differences in skill level or prior training exposure. The choice criteria had also focused much on physical fitness, the frequent participation in the shooting practice and lack of any medical condition that would affect the participation in the balance or shooting tasks.

According to ethical research practices, the participants were appraised on purpose, procedures and risks and benefits of the study. Participants provided informed consent, and the participation was voluntary, and they could withdraw at any time without consequences. Confidentiality and anonymity were also maintained during the study and the data collected were handled with high care to preserve privacy. The protocol of the study was also approved

by the institutional ethics committee; in this way they fulfilled the accepted ethical principles of sports science research.

Training Program Description

the present study included a systemic 45-days training program aimed at improving shooting performance and postural balance of male shooters through stability, precision and concentration exercises. The program was well designed to combine theoretical knowledge as well as practical applications enabling participants to develop important physical and psychological skills for competitive shooting. The exercises were gradually designed so as to achieve gradual enhancement of postural control, fine motor skills, and mental focus.

The training regimen consisted of static shooting drills, stability exercises, and concentration tasks all in the interest of precision of shooting and better balance control in performance. Under controlled conditions, participants did static shooting drills to build consistency and accuracy, focusing on correct posture, grip, and trigger control. Stability exercises including single-leg stands, wobble board drills and dynamic balance tasks were integrated in order to enhance postural stability and plantar oscillation when shooting. Concentration tasks consisted of mental imagery and focus control activities, and breathing exercises that aimed at improving shooters' capacity to remain calm and focused during pressure.

Each training session was conducted six days a week for about 60 to 90 minutes to provide sufficient exposure and involvement with the subject matter of the training. The training program was based on the progressive overload principle, and it became gradually more complex and difficult to test the physical and cognitive limits of the athletes during six weeks. Participants got regular feedback and corrections from competent coaches, which made the intervention even higher in quality and effectiveness.

During the program, pre and post test was carried out to assess the improvement of shooting accuracy and balance performance; establishing a system for data collection and analysis. This carefully designed training program was the central intervention strategy upon which the systematic measurement of its impact on the targeted performance variables was based.

Data Collection Methods

The methods of data collection in this study were well thought out to yield objective and subjective information on shooting performance, control of balance, and participants' perceptions. Various tools and techniques were used to ensure that an extensive assessment of the effects of the 45-day training program is done.

Shooting performance assessment was performed with the help of standardized pistols under very strict conditions to make the data reliable and valid. Participants were required to do a set of shooting tasks before and after the intervention. Scores for shooting were taken according to precision and accuracy following official scoring protocols. The pre- and post-tests enabled direct comparison of performance improvements due to the implemented training program.

For measuring the balance and postural stability of the participants at shooting, Center of Pressure (C.O.P.) analysis was performed with the help of the BTS S.p.A. biomechanical analysis system. This equipment enabled accurate real time measurements of plantar oscillation because it acquired C.O.P. trajectories as participants engaged in shooting tasks. Oscillation area, trajectory length, and directional sway were the parameters used to quantify balance control and stability improvements before and after the training program. This objective data allowed gaining important insights on the way stability and balance exercises affected the shooting posture of the athletes and their performance.

Apart from the objective performance measures, surveys and questionnaires were used to measure the participants' subjective feelings, confidence, perceived stability and satisfaction with the training program. Both Likert-scale questions and open-ended questions were part of the questionnaires to help participants explain their opinions and experiences. Tools used for this purpose were piloted tested in order to ensure clarity and reliability. This triangulation of objective and subjective data sources increased the validity of the research findings by getting an overall picture of the effectiveness of the training program from a performance and psychological point of view.

Instruments Used

The instruments used in this study were therefore highly selected to guarantee reliable acquisition and analysis of objective performance data and subjective participant feedback. Every tool was critical in the assessment of the effect of the 45-day training program on shooting performance and balance control.

Subjective data on participants' perceptions about their confidence, stability and satisfaction with the training program were collected using questionnaires. Respondents used Likert-scale items to rate their answers and provided more detailed feedback through open-ended questions. These instruments were pilot tested for clarity, reliability and consistency of responses. Participants' questionnaires gave information on their psychological reaction to training, showing how much they thought they improved at shooting and balancing, and how satisfied

they were with the program. This tool was very important in triangulating data with the target performance metrics.

The BTS S.p.A. biomechanical tool was applied to record Center of Pressure (C.O.P.) trajectories during shooting tasks. This advanced tool provided real-time information about postural stability since it measured balance control using such parameters as length of trajectory, area of oscillation and directional sway. The C.O.P. measurements were at the heart of the analysis of the effect of stability exercises on postural control during shooting as they provided a detailed and objective evaluation of balance changes. As a well-known instrument in biomechanics, the BTS S.p.A. tool is characterized by high accuracy and reliability of its readings.

Finally, SPSS (Statistical Package for the Social Sciences) software was employed for statistical analysis of collected data. With SPSS, different statistical methods were applied, such as paired t-tests for performance comparisons before and after the intervention and descriptive statistics to present data patterns. SPSS helped conduct a deep analysis of shooting scores and C.O.P data, correlation analysis to determine relationships between balance improvements and shooting accuracy. The capabilities of the software were critical for strict and scientifically valid conclusions from the data.

Data Analysis Techniques

The data from the study were analyzed using a combination of statistical tests, description and correlation analysis, Center of Pressure (C.O.P.) static analysis to critically determine the impact of the 45-day training program on shooting performance and balance control.

Statistical tests were used to know if there were significant differences between participants performance before and after the intervention. The paired t-test was the main statistical technique employed in which pre and post intervention shooting scores and C.O.P. measurements were compared. This test enabled identification of statistically significant improvement in performance, so that observed changes were not due to chance. Paired t-test was selected as it is perfect for comparing two associated samples, as in this case, the repeated measures obtained from each participant before and after the training program.

Apart from paired t-test, descriptive and correlation analysis were performed to give a clear picture of the data. Means, standard deviations, percentages and other descriptive statistics were used to describe the shooting scores and C.O.P. measurements. These statistics were useful in providing quantitative measures of the general improvement of performance and

balance. Balance improvement relationship with shooting accuracy was investigated using correlation analysis. Through analysis of the strength and direction of these relationships, the study was able to identify how improvements in postural stability were associated with improved shooting performance, providing useful insights to the interplay between physical and psychological factors in shooting sports.

Finally, C.O.P static analysis was used to determine the balance control of the participants in shooting tasks. C.O.P. analysis of the data from the BTS S.p.A. biomechanical tool determined the parameters of trajectory length and oscillation area to quantify postural stability. These metrics were used to monitor shifts in balance control before and after the intervention, with objective evidence of the way in which the stability exercises affected the participants' ability to maintain a stable shooting posture. The C.O.P. static analysis was essential in determining the success of the balance exercises and providing a detailed image of how stability improvements led to improved shooting performance.

Scope and Delimitations of the Study

The objective of this study was to investigate the impact of stability, precision and concentration exercises on male shooting sports athletes' shooting performance and balance control. The research was carried out in the limits of Lakshmibai National Institute of Physical Education (LNIPE), Gwalior and was devoted to 45 male athletes who previously received training in shooting sports. The scope of the study was restricted to this group of participants, thus a homogenous sample was obtained with similar training backgrounds, which enabled the targeted evaluation of the effects of the training program.

The purpose of the study was to establish causative relationships between the training interventions (stability, concentration, and precision exercises) and enhanced shooting accuracy and postural stability (measured through Center of Pressure (C.O.P.) analysis). In addition, the study sought to evaluate the physical performance (shooting scores and balance measurements) and the psychological aspects (confidence and satisfaction) of the participants, and thus present a comprehensive picture of the ways targeted training affects shooting ability. The results of the present research can be used for the improvement of training programs that incorporate both physical and mental aspects of shooting sports.

Notwithstanding its all-round approach, the study had a number of limitations that should be taken into account when analyzing the findings. Because the study used only 45 male athletes who were quite similar, the findings might not apply to female athletes or those with different

experience levels in shooting. The findings of the study, therefore, are therefore applicable to the selected group of male shooters in the controlled institutional setting.

Another limitation was the limited time for the intervention, which happened for 45 days. Although this period enabled observable changes in shooting performance and balance, it might not be sufficient to detect long-term training effects or find out whether the observed changes are maintained with time. Further research may be improved by increasing the length of the intervention to record long-term changes and skills retention.

Also, using questionnaires to gather self-reported data can lead to social desirability bias, since participants might have tried to answer in a way they thought the researchers wanted. Although this was alleviated by using objective performance metrics, the subjective nature of the feedback could color the interpretation of the overall perceived improvements of participants. Lastly, the study was carried out in an institution where specialized equipment and resources used are not always available in all shooting settings. As such, the findings may not be entirely applicable to low resource settings or training facilities that are different. The applicability of the results to settings where such advanced equipment is not available can also be constrained by the use of certain biomechanical tools such as the BTS S.p.A. equipment.

Significance of the Study

This research adds to the academic knowledge about the complicated relationship between physical stability, psychological concentration, and shooting performance. By concentrating on the integrated results of stability, precision, and concentration drills, this research extends existing literature in the area of sports science, especially in shooting sports. The innovative use of Center of Pressure (C.O.P.) analysis as an objective measure of balance and stability while performing shooting tasks offers new angles to how postural control may affect accuracy of shooting. This work therefore makes significant contributions to biomechanics and sports psychology, providing a new look at the physical and mental aspects of performance improvement in shooting sports. What is more, the findings can guide future research directions, towards the study of similar interventions in other high-precision sports, and development of broader training models.

The practical value of this study is the possibility to improve the training programs of the athletes practicing shooting sports. The outcomes of this research provide the evidence that the stability, precision, and concentration exercises, when added to a training schedule, may help to enhance shooting performance and balance control, which are essential for shooting sports

success. By showing the effectiveness of those targeted exercises the study indicates that coaches and trainers can use more holistic training which will not only concentrate on physical conditioning but also on mental focus and stability.

The training implications are further extended to specific training program designs that will focus on enhancing the postural stability of shooters, as was shown in this study, which can directly affect shooting accuracy. The implementation of biomechanical tools including C.O.P. analysis into everyday training may allow coaches to monitor the balance and stability improvement of athletes and introduce more individual and data-oriented measures to performance improvement. In addition, results of the study highlight the need to include psychological exercises that aim at concentration and mental concentration to maximize general shooting skills. Therefore, this research offers practical recommendations for designing more efficient and extensive training systems not only for the shooting sports but also for the other precision sports that involve fine motor skills and mental toughness.

Tentative Chapterization Plan

1. Introduction
2. Review of Literature
3. Research Methodology
4. Data Analysis and Results
5. Conclusions and Recommendations

References

1. Anderson, G. S., & Plecas, D. B. (2000). Predicting shooting scores from physical performance data. *Policing: An International Journal of Police Strategies & Management, 23*(4), 525-537. https://doi.org/10.1108/1363951001035561 1
2. Cenciarini, M., Loughlin, P. J., Sparto, P. J., & Redfern, M. S. (2010). Stiffness and damping in postural control increase with age. *IEEE Transactions on Biomedical Engineering, 57*(2), 267–275. https://doi.org/10.1109/TBME.2009.2023684
3. Horak, F. B. (2006). Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls? *Age and Ageing, 35*(suppl_2), ii7–ii11. https://doi.org/10.1093/ageing/afl077
4. Hrysomallis, C. (2011). Balance ability and athletic performance. *Sports Medicine, 41*(3), 221+. https://link.gale.com/apps/doc/A250824395/HRCA?u=anon~2f2d770d&sid=googleScholar&xid=9cd806ea

5. Jeka, J., Kiemel, T., Creath, R., Horak, F., & Peterka, R. (2004). Controlling human upright posture: Velocity information is more accurate than position or acceleration. *Journal of Neurophysiology, 92*(4), 2368–2379. https://doi.org/10.1152/jn.00198.2004
6. Krawczyk-Suszek, M., Martowska, B., & Sapuła, R. (2022). Analysis of the stability of the body in a standing position when shooting at a stationary target—a randomized controlled trial. *Sensors, 22*(1), 368. https://doi.org/10.3390/s22010368
7. Mononen, K., Konttinen, N., Viitasalo, J., & Era, P. (2007). Relationships between postural balance, rifle stability, and shooting accuracy among novice rifle shooters. *Scandinavian Journal of Medicine & Science in Sports, 17*(2), 180–185. https://doi.org/10.1111/j.1600-0838.2006.00549.x
8. Mileti, I., Taborri, J., Rossi, S., del Prete, Z., Paoloni, M., Suppa, A., & Palermo, E. (2020). Reactive postural responses to continuous yaw perturbations in healthy humans: The effect of aging. *Sensors, 20*(1), 63. https://doi.org/10.3390/s20010063
9. Peterka, R. J. (2002). Sensorimotor integration in human postural control. *Journal of Neurophysiology, 88*(3), 1097–1118. https://doi.org/10.1152/jn.2002.88.3.1097
10. Peterka, R. J., & Loughlin, P. J. (2004). Dynamic regulation of sensorimotor integration in human postural control. *Journal of Neurophysiology, 91*(1), 410–423. https://doi.org/10.1152/jn.00830.2003
11. Ravindra, S. Goonetilleke, Errol R. Hoffmann, & Wing Chung Lau. (2009). Pistol shooting accuracy as dependent on experience, eyes being opened and available viewing time. *Applied Ergonomics, 40*(3), 500–508. https://doi.org/10.1016/j.apergo.2008.09.005
12. Shumway-Cook, A., Anson, D., & Haller, S. (1988). Postural sway biofeedback: Its effect on reestablishing stance stability in hemiplegic patients. *Archives of Physical Medicine and Rehabilitation, 69*(6), 395–400. https://doi.org/10.1016/0003-9993(88)90064-9